2008 年畜養原魚の年齢組成の解析

Analysis of age composition of southern bluefin tuna used for farming in 2008

伊藤智幸 [1]・坂本孝明 [2]・山本隆久 [2]

Tomoyuki ITOH[1], Takaaki SAKAMOTO[2] and Takahisa YAMAMOTO[2]

1: National Research Institute of Far Seas Fisheries　遠洋水産研究所

2: Fisheries Agency of Japan　水産庁

要約

オーストラリアのミナミマグロ養殖魚について、2008 年の出荷時のサイズデータから年齢組成を推定した。月別体長組成に正規分布を当てはめた結果、2 歳魚 12%、3 歳魚 85%、4 歳魚 2%、5 歳魚 1%と推定された。2008 年漁期のまき網による総漁獲重量は 5798 から 6647 トンの間と推定された。これらは豪州政府からの報告値と大きく異なっている。40 尾サンプリングのバイアスに関する早急な検証と、豪州巻き網漁業による漁獲量及びサイズ組成を把握する方法の改善が必要である。

Summary

The age composition of southern bluefin tuna (SBT) caught by Australian purse seine fisheries and used for farming was estimated based on size data from the harvest in 2008.　We carried out the age decomposition based on the length frequencies using the framework of a mixture of normal distributions, estimated independently for each month.　The age compositions was estimated as 12% for age 2, 85% for age 3, 2% for age 4 and 1% for age 5.　The total catch of the Australian purse seine fisheries in the 2008 fishing season was estimated to be within a range of 5798 to 6647 tons.　This figure is 11-28% larger than the reported Australian purse seine catch (5211 tons).　The age-composition estimated in this analysis should replace the current adjustments made in age composition for historical data and be used for stock assessment by the Extended Scientific Committee.　Urgent examination of the bias in the 40 fish sampling, which is used by Australia to calculate its reported purse seine catch, and improvement of method to obtain the age composition and amount caught by the Australian surface fishery is required.

緒言　Introduction

年齢別漁獲尾数、漁獲重量は CCSBT における資源評価において重要な情報である。本研究では豪州養殖魚の 2008 年の年齢別漁獲尾数や重量を、収穫時のサイズ測定データに基づいて推定する。2007 年畜養魚については、別文書（CCSBT/ESC/0909/29）で結果を示した。

Accurate data on catch-at-age by number as well as the total catch in weight are essential for stock assessment and management of southern bluefin tuna (SBT) in the CCSBT. In this document we present estimates of the catch-at-age and the total catch in 2008 of the Australian surface fishery for SBT farming based on size data at harvest. Similar analysis of SBT farmed in 2007 is presented in CCSBT/ESC/0909/29.

材料と方法　Materials and Methods

2007 年 5 月以降に日本に輸入する畜養ミナミマグロについては、個体ごとの体長及び体重を報告するよう、農林水産省が輸入業者に対して指示をした。2009 年 3 月までに収集、入力されたデータを解析に用いた。Table 1 に月別収集個体数を示す。若干の体長、体重値のエラーレコードを除いた 94,384 個体を解析対象とした。

体長（尾叉長 cm）と体重（鰓と内臓を除いた製品重量 kg）の両方が得られたデータ(N=57,233)を用いて、体重体長換算式のパラメータ値を計算した。収穫月別に有意に異なった（F=132、p<0.01）ことから、式(1)の換算のパラメータ値は月別に求めた（Table 2、Fig.1）。

$$FL = a_i \times PW^{b_i}, \qquad (1)$$

ここで、FL は尾叉長(cm)、PW は体重(kg)、i は収穫月、a_i、b_i は月別の定数。

求めた体重体長換算式を用いて、収穫時サイズデータの体重データを体長に変換し、出荷状態（生鮮、冷凍運搬船、冷凍コンテナ）別、月別に 1cm 階級ごとにまとめた。この体長組成を式(2)によって 1-4 個の正規分布に分解した。適当な初期値について残差平方和が最小となるよう Gauss-Newton algorithm による非線形最小二乗法でパラメータベクトル Θ（$\mu_2, \mu_3, \mu_4, \mu_5, \sigma_2, \sigma_3, \sigma_4, \sigma_5, k_2, k_3, k_4$）の最大 11 パラメータの解を求めた。なお、$\sum_{i=2}^{n} k_i = 1$ により、最高齢の k_i は計算できる（e.g. $k_4=1-k_2-k_3$)ので、推定不要である。正規分布の数は、解が得られ、得られた平均値、標準偏差が妥当（e.g. $\mu_2<\mu_3<\mu_4$, $\sigma_4<6$）である最大のものを選択した。

$$SSQ = \sum_{x=\min L}^{\max L} \left(H_x - \sum_{\alpha=2}^{n} k_\alpha \frac{1}{\sqrt{2\pi\sigma_\alpha^2}} \exp\left(-\frac{(x-\mu_\alpha)^2}{2\sigma_\alpha^2} \right) \right)^2 \qquad (2)$$

ここで、

x：1cm ごとの体長階級

$minL$：最小体長階級

$maxL$：最大体長階級

H_x：x cm の体長頻度

n：正規分布区分数（1,2,3,4 のいずれか）

2008 年までと異なり、体長分布の正規分布と年齢との対応が解釈困難な場合があり、3 歳と 4 歳の中間的な位置に正規分布の平均値が位置した場合もあった。そこで正規分布と年齢の対応は、最も可能性が高いと思われる場合（Base case）、低年齢に対応すると仮定した場合（Lower age case）、高年齢に対応すると仮定した場合（Higher age case）のそれぞれで年齢組成を求めた。

続いて、日本に輸入された魚全体に対する推定に拡張した。日本に輸入された収穫月別尾数を、輸入統計（日本が CCSBT に提出）の月別製品重量から計算した。生鮮魚は収穫月に輸入されるとした。冷凍魚は、収穫時サイズデータにおける収穫月と報告月との関係を集計した結果から、3 月、4 月、7 月の輸入はそれぞれの月に収穫され、8 月の輸入は 7 月に収穫、9 月以降の輸入は 8 月に収穫されたとした。次式(3)で尾数を求めた。

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \qquad (3)$$

ここで、

$n_{i,k}$：収穫 i 月、生鮮冷凍 k の輸入尾数

$W_{i,k}$： i 月に収穫された生鮮冷凍 k の輸入重量(kg)

$A_{i,k}$：ハーベストデータから求めた収穫 i 月、生鮮冷凍 k の平均体重 (kg)

日本に輸入された魚全体の年齢別漁獲尾数は、サイズ測定個体数が全体の一部であるので、ブートストラップ（1000 回のリサンプリング）で信頼範囲を求めた（式 4）。冷凍魚の年齢組成は、冷凍運搬船と冷凍コンテナ船それぞれの年齢組成に対して、それぞれの測定個体数で重み付けをした（式 5）。まき網で漁獲した時点の体重を掛けて漁獲重量を求めた。CCSBT で使用している 1 月 1 日時点の各年齢の体長間を直線補完して、収穫時サイズデータにおいて最も生け込み時期頻度が高かったのが 2 月であったことから、2 月 1 日時点の体長に対応する体重を、Robins(1963)の関係式から推定した。

$$n_{\alpha} = \sum_{k=1}^{2}\sum_{i=4}^{10}\left(sample(m_{i,k} \times k_{\alpha,i,k}, n_{i,k}) \times \frac{n_{all}}{\sum_{i=4}^{10} n_{i,k}} \right) \qquad (4)$$

$$w_{import} = \sum_{\alpha=2}^{5} n_{\alpha} \times A \times FL_{\alpha,2}^{B} \qquad (5)$$

ここで、

n_{α}：日本に輸入された α 歳魚の尾数

w_{import}：日本に輸入された魚の原魚重量合計

$m_{i,k}$：ハーベストデータにおける収穫 i 月、生鮮冷凍 k の測定尾数。

$n_{i,k}$：収穫 i 月、生鮮冷凍 k の輸入尾数。(3)式で求めた。

$k_{\alpha,i,k}$：収穫 i 月、生鮮冷凍 k、 α 歳の個体数割合。(2)式で求めた。

n_{all}：日本に輸入された尾数の総数。2 月は年齢組成を推定していないため補正した。

$FL_{\alpha,i}$：野生魚の漁獲 i 月、α 歳の体長(cm)。

A,B：尾叉長－原魚重量の関係式　$原魚重量 = A \times 尾叉長^B$　の係数。

$sample(x,y)$：サンプルデータ x から y 個をリサンプリングする。

次いで、年齢別漁獲尾数および漁獲重量を豪州まき網による総漁獲尾数に引き伸ばした(式 6、式 7)。

$$N_\alpha = n_\alpha \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \quad (6)$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_\alpha} \quad (7)$$

ここで、

N_α：豪州まき網が漁獲した α 歳魚の尾数

PSW：豪州まき網が漁獲したミナミマグロの重量（kg）

N_{all}:　2007 年 12 月から 2008 年 3 月までに豪州がまき網で漁獲した合計尾数。324,754 尾。日本輸入物には含まれない畜養中の死亡魚や米国、EC への輸出を考慮。

比較対照とすべき豪州まき網の月別年齢別漁獲尾数は、2009 年 8 月 1 日時点において、豪州から報告されていなかった。そこで、豪州が報告した月別体長別漁獲尾数データ（AU_Catch_at_Length_08.xls）に対して日本が通常用いている体長から年齢への変換プログラムを用いて、2008 年の月別年齢別漁獲尾数を求めた。日豪の年齢変換は月の基準などにわずかな違いがあるので、この推定値は本研究用の暫定的なものである。

分析には R（Version 2.8.1 for Windows）を用いた。

The Ministry of Agriculture, Forestry and Fisheries of Japan requested importers to submit data on the length and weight at harvest of farmed SBT which is imported to Japan after May 2007.　The data on farmed SBT imported to Japan in 2008, which were collected from May 2008 to March 2009 were used for the analysis.　A total of 94,384 individual records were analyzed after removing several anomalous records among the data collected data (Table 1).

Using data for 57,233 individuals for which both length and weight information is available, parameters for the weight-length relationship were estimated by applying the least squares method for logarithmic scaled length (fork length in cm) and weight (gilled and gutted in kg) as follows:

$$FL = a_i \times PW^{b_i}, \quad \text{(Eq-1)}$$

where FL is the fork length in cm, PW is the processed weight (gilled and gutted with tail) in kg, and a_i and b_i are month-specific parameters to be estimated.　Because the fatness index (PW/FL^3) differed significantly by month (F = 132, $p < 0.01$), the weight-length relationships were estimated by month (Table 2, Fig. 1).

Weight values were converted to length by using the monthly weight-length relationships. Next, length frequencies by one centimeter bin by month and by classes of markets/fates (fresh, frozen fish from freezer vessels and frozen fish from freezer containers) were produced (Fig 2). From one to four normal distributions were fitted to decompose the length frequency by minimizing Eq-2. The largest dimension considered for the parameter vector Θ ($\mu_2, \mu_3, \mu_4, \mu_5, \sigma_2, \sigma_3, \sigma_4, \sigma_5, k_2, k_3, k_4$) was 11. This vector includes the mean, standard deviation and relative strength of each normal distribution, and these were estimated by the non-linear least squares method with the Gauss-Newton algorithm to minimize the sum of squares. Because k_i of the maximum age can be calculated from $\sum_{i=2}^{n} k_i = 1$ (e.g. $k_4=1-k_2-k_3$), the number of parameters to be estimated can be reduced by one. Among the cases with two to four normal distributions, the case with the maximum number of distributions which nevertheless gave appropriate means and standard deviations (e.g. $\mu_2<\mu_3<\mu_4$, $\sigma_4<6$) was chosen.

$$SSQ = \sum_{x=\min L}^{\max L} \left(H_x - \sum_{\alpha=2}^{n} k_\alpha \frac{1}{\sqrt{2\pi\sigma_\alpha^2}} \exp\left(-\frac{(x-\mu_\alpha)^2}{2\sigma_\alpha^2} \right) \right)^2 \qquad \text{(Eq-2)}$$

where,

x: Length class of one centimeter bin,
$minL$: Class of the minimum length,
$maxL$: Class of the maximum length,
H_x: Frequency in length class of x cm,
n: Number of age classes among 1, 2, 3, and 4.

In contrast to previous years, age assignment was difficult for some normal distributions estimated for which the mean body length was located in the middle of lengths expected for age 3 and age 4. Therefore, age compositions were estimated for three cases; the most likely (Base case); means assigned to lower age for the normal distributions for which this was difficult to judge (Lower age case); and means assigned to higher age for the normal distributions difficult to judge (Higher age case).

The estimation was then expanded from samples for which the size was measured to all of the farmed SBT imported to Japan. The total number of SBT imported to Japan by month was calculated from the monthly total SBT product weight in the Japan Import Statistics which have been submitted to CCSBT (Eq-3). Fresh fish were assumed to be imported in the same month that they were harvested. For frozen fish, information of harvest month and imported month were analyzed using the size data at harvest, and it was inferred that SBT imported in March, April and July were harvested in the same month, but that SBT imported in August were harvested in July, and SBT imported after September were harvested in August.

$$n_{i,k} = W_{i,k} \times \frac{1}{A_{i,k}} \quad \text{(Eq-3)}$$

where

$n_{i,k}$: Number of SBT imported in harvest month *i* of fresh/frozen state *k*,

$W_{j,k}$: Weight of SBT imported in month *j* of fresh/frozen state *k* (kg),

$A_{i,k}$: Average body processed weight of SBT in harvest month *i* of fresh/frozen state *k* based on harvest data (kg),

Confidence intervals for the estimated age composition (in number) of SBT imported to Japan were calculated using bootstrapping (1000 resamples) (Eq 4). Age compositions for frozen SBT were weighted by the number of fish measured from freezer vessels and from freezer containers. The weight of imported SBT at the time of the purse seine catch was calculated (Eq 5). As transfer from towing pens to farming cages was most frequent in February for the individual size data used in this analysis, length as at 1st February was calculated based on information on the length at age on 1st January, which is as used in CCSBT, and on interpolation. Finally, the calculated length on 1st February was converted to body weight using the length-weight relationship for wild fish in southern Australia (Robins 1963).

$$n_{\alpha} = \sum_{k=1}^{2}\sum_{i=4}^{10}\left(sample(m_{i,k} \times k_{\alpha,i,k}, n_{i,k}) \times \frac{n_{all}}{\sum_{i=4}^{10} n_{i,k}} \right) \quad \text{(Eq-4)}$$

$$w_{import} = \sum_{\alpha=2}^{5} n_{\alpha} \times A \times FL_{\alpha,2}^{B} \quad \text{(Eq-5)}$$

where

n_{α}: Number of SBT in age α imported to Japan,

w_{import}: Total weight of whole SBT imported to Japan,

$m_{i,k}$: Number of fish measured in harvest month *i* of fresh/frozen state *k,*

$n_{i,k}$: Number of SBT imported in harvest month *i* of fresh/frozen state *k.*as estimated using Eq-3,

$k_{\alpha,i,k}$: Proportion of number of age *a* SBT in harvest month *i* of fresh/frozen state *k* as estimated by minimizing Eq-2,

n_{all}: Total number of SBT imported to Japan from Australia. This adjusts the total number of SBT harvested by including a correction for SBT harvested in February when the age composition was not estimated due to the small number of SBT harvested,

$FL_{\alpha,i}$: Length at month of catch *i* of age *a* SBT (cm),

A,B: Parameters of length-weight relationship of *Whole weight=A x Forlk length*^{B}, *sample(x,y)*: resample *y* individual data from sample size of *x*.

In the next step, the catch-at-age and catch weight were scaled upwards to the total number of SBT caught by Australian purse seiners (Eq-6 and Eq-7).

$$N_{\alpha} = n_{\alpha} \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_{\alpha}} \qquad \text{(Eq-6)}$$

$$PSW = W_{import} \times \frac{N_{all}}{\sum_{\alpha=2}^{5} n_{\alpha}} \qquad \text{(Eq-7)}$$

where

N_{α}: Total number of age *a* SBT caught by Australian purse seine,

PSW: Weight of Australian purse seine catch (kg),

N_{all}: Total number of SBT caught by Australia between December 2007 and March 2008 (324,754 individuals). This includes SBT not imported to Japan, i.e. died during farming or exported to other countries, such as U.S.A and EU.

Catch-at-age by month that might be compared with the present estimates were not provided in the CCSBT data exchange process on 1st August 2009. Therefore, we estimated the catch-at-age of Australian purse seine in 2008 using catch-at-size data (AU_Catch_at_Length_08.xls) and our program that converts length to age. This program yields almost identical catch-at-age estimates to those which would be produced by Australian scientists, with the difference arising from a different definition of month.

The computer package R, version 2.8.1 for Windows, was used for the calculations conducted.

結果と考察　**Results and Discussion**

パッキングリストにおけるサイズデータは 2 月から 10 月まで収集され、多くの月で 5000 個体以上であった。日本の輸入個体数に対し、生鮮魚の 73%、冷凍魚の 22%、全体の 29%をカバーした（Table 3）。

2008 年 4 月から 8 月の生鮮用、冷凍運搬船用、冷凍コンテナ用で区分した全ての体長頻度は、1 個から 4 個の正規分布に分解された（Fig.2, Table 4）。グラフ上で、求めた混合正規分布は、7 月の生鮮用以外は体長頻度に良くフィットしていることが分かる。体長 130cm 以上については正規分布がカバーできていない部分もあり、これはわずかにサイズや年齢の過小推定につながる。

正規分布の平均値は、体長約 95cm、約 106cm、約 115cm、約 130cm に見られた。野生魚の年齢

別体長と比較すると、平均値 106cm の正規分布は 3 歳、約 130cm の正規分布は 5 歳に相当すると判断された。

しかし体長約 95cm の正規分布は標準偏差が大きく推定された場合もあり（生鮮の 7 月、冷凍運搬船の 7 月、8 月、冷凍コンテナの 8 月）、必ずしも 2 歳には対応していなかった。ベースケースではこれらを全て 3 歳魚とみなした。低年齢を仮定したケースでは生鮮、冷凍運搬船の 7 月の魚が 2 歳魚とみなして計算したが、2 歳魚はその一部で多くは 3 歳魚であったと思われ、低年齢を仮定したケースは過小の年齢組成を示しているだろう。

体長約 115cm の正規分布については 3 歳と 4 歳の境界付近に位置し､判断が困難であった｡2007 年畜養魚については平均値が約 120cm に見られて 4 歳と判断できたのと異なっていた。今回の解析ではこれらを 3 歳としてベースケースにしたが、年齢を過小に推定したものであろう。ベースケースと高齢を仮定したケースの中間的なものが真の値に最も近いと思われる。

サイズデータのカバー率が高かったことならびに 3 歳魚が多くを占めるという割合が生鮮／冷凍、月に関わらず同様であったことから、ブートストラップで推定した母集団（日本への輸出個体全体）の年齢別尾数範囲及び合計重量における分散は小さかった(Table 6)。冷凍運搬船と冷凍コンテナ船とで扱われた魚の年齢組成（8 月にのみ両者が得られた）はほとんど同じであった。

豪州からは、まき網による年齢別漁獲尾数、漁獲重量が報告されている。2007 年 12 月に漁獲された魚は 2008 年の 1 歳高齢の魚に含めた。本解析による年齢組成（2 歳魚 12%、3 歳魚 85%、4 歳魚 2%、5 歳魚 1%）と豪州報告の年齢組成（2 歳魚 24%、3 歳魚 71%、4 歳魚 4%）とは、大きな食い違いがある（Table 6、Fig. 3）。低年齢に当てはめた場合、高年齢に当てはめた場合でも、食い違いは依然として見られる。

また 2008 年漁期のまき網の漁獲量も豪州が報告する 5,211 トンに対して、本推定ではベースケースで 5,798 トン、高年齢を当てはめた場合で 6,647 トンと異なった。

これらの年齢組成、漁獲量の不確実性は資源推定に大きなバイアスをもたらすものである。漁獲量及びサイズ組成を報告するために豪州が用いている 40 尾サンプリングのバイアスに関する早急な検証と、豪州巻き網漁業による漁獲量及びサイズ組成を把握する方法の改善が必要である。

The size data collected between February and October and covered 29% (73% of fresh, 22% of frozen) of SBT imported to Japan from Australia (Table 3). The numbers of size records exceeded 5000 individuals in many months.

All of the monthly length frequencies between April and August 2008 were decomposed into between one and four normal distributions for each of fresh SBT, frozen SBT from freezer vessels and frozen SBT from freezer containers (Table 4 and Fig. 2). The mixture of normal distributions fitted the length frequency distributions well, except for fresh SBT in July for which an interpretation in terms of a superposition of successive years' cohorts is not obvious (see Fig. 2). No normal distribution was estimated for large fish of more than 130 cm FL, whose length frequency distribution did not show a peak in some months (e.g. fresh SBT in July in Fig. 2a and frozen fish from freezer containers in October in Fig. 2c). This leads to a slight underestimation of the age composition for higher ages.

The mean values of the normal distributions were around 95 cm FL, 106 cm FL, 115 cm FL and 130 cm FL. Comparison to the length-at-age of wild fish suggests that the normal distribution with 106 cm mean corresponded with age 3 and that with 130cm mean did so with age 5 (Table 5).

Some of the normal distribution with 95 cm mean are however estimated to have large standard errors (fresh in July, freezer vessel in July and August, and freezer container in August), and did not correspond with age 2. These were assumed to be age 3 for the base case (Table 5). In the lower age case, although fresh and freezer vessel SBT in July were assumed to be of age 2, a large part of the normal distribution seemed to contain age 3 SBT, which would lead to under-estimation of age.

The age of some normal distributions with 115 cm mean were difficult to judge because 115 cm in length locate in the middle of age 3 and age 4. This situation is different from that for 2007 farmed SBT the normal distribution with 120cm mean was readily assigned to age 4. In the present calculation, these normal distribution were assumed to be age 3 for base case, but this would reflect an under-estimation of age. The true value would likely be between the base case and the higher age case.

Variances of estimated number of fish by age and estimated total weight of the all SBT imported to Japan obtained from bootstrapping were small (Table 6). This is due to the facts that coverage of the size data was high and that age compositions (for which age 3 was dominant followed by age 4) were similar in all months for both fresh and frozen SBT. Age compositions for freezer vessels and freezer containers, which are possible only for August, were quite similar to each other.

Catch by age and the total amount of catch by purse seiners have been reported by Australia. SBT caught in December 2007 were included as fish one year older in 2008 so that they were treated as the same cohort. There is a substantial difference between estimates from the present study (12 % for age2, 85 % for age 3, 2 % for age 4 and 1% for age 5) and the reported age compositions (24 % in age2, 71 % in age 3 and 4 % in age 4) by Australia (Table 6, Fig. 3). Substantial differences were also observed for the lower and higher age cases. The estimated age-composition should replace the adjustments made in age composition for historical data to be used for the stock assessment by the Extended Scientific Committee.

Australia reported that the total amount of Australian purse seine catch in the 2008 fishing season was 5,211 tons. However, the total amount estimated in the present study is 5798 tons for the base case (the estimate for the lower age case is almost the same) and 6647 tons in the higher age case (Table 6).

Uncertainties concerning age composition and the total amount of catch give rise to difficulties in the stock assessment of SBT within the CCSBT. Urgent examination of bias in the 40 fish sampling, which is used by Australia to prepare its reported catch and size compositions, and improvement of method to obtain age compositions and the amount caught by the Australian surface fishery are required.

References

Itoh, T., T. Sakamoto, T. Yamamoto 2009. Follow-up analysis on age composition of southern bluefin tuna used for farming in 2007. CCSBT/ESC/0909/29.

Robins, J. P. 1963. Synopsis of biological data on bluefin tuna *Thunnus thynnus maccoyii* (Castelnau) 1982. Species synopsis No. 17. FAO Fisheries Biology Synopsis No. 60.

Table 1. Number of size data collected by month for Australian farmed SBT harvested and imported to Japan in 2008

2008 年に収穫され日本に輸入された畜養ミナミマグロの月別サイズデータ数

Month of harvest	N_collected	N_collected and anomalous data removed	N_Length & Weight obtained
Feb	93	93	93
Apr	520	520	430
May	4,492	4,492	3,513
Jun	5,648	5,647	4,404
Jul	3,841	3,840	3,108
Aug	36,680	36,666	25,049
Sep	36,620	36,618	14,327
Oct	5,572	5,571	5,372
Dec	937	937	937
Total	94,403	94,384	57,233

Table 2. Parameters for conversion from processed weight to fork length by month for Australian farmed SBT harvested in 2008

2008 年に収穫された畜養ミナミマグロの月別の体重体長関係パラメータ値

Month	N	a	b
2	93	35.742	0.340
3	430	40.785	0.301
4	3,513	35.074	0.344
5	4,404	36.954	0.329
6	3,108	39.290	0.310
7	25,049	40.397	0.303
8	14,327	39.303	0.311
9	5,372	36.755	0.332
10	937	38.699	0.320

Table 3. Number of weight data collected, estimated number of farmed SBT imported to Japan and their proportion by month of harvest for Australian farmed SBT in 2008

2008 年の畜養ミナミマグロの収穫月別の体重測定尾数と日本への輸入尾数推定値、体重測定個体数割合

Harvest month	Number of weight data collected (A)				Estimated number of farmed SBT imported in Japan (B)			Proportion (=A/B)		
	Fresh	Frozen	Frozen(Freezer vessels/Container)	Total	Fresh	Frozen	Total	Fresh	Frozen	Total
2	93			93						
3	520			520	528	3,563	4,091	99%	0%	13%
4	4,492			4,492	5,729	16,782	22,511	78%	0%	20%
5	5,647			5,647	8,273		8,273	68%		68%
6	3,840			3,840	5,714		5,714	67%		67%
7	5,613	31,053	(31053 / 0)	36,666	7,763	41,236	48,999	72%	75%	75%
8	6,338	30,248	(17483 / 12765)	36,586	9,145	213,547	222,692	69%	14%	16%
9	5,571			5,571	6,375		6,375	87%		87%
10	937			937	1,855		1,855	51%		51%
Total	33,051	61,301	(48536 / 12765)	94,352	45,381	275,129	320,510	73%	22%	29%

Table 4. Estimated mean length, standard deviation and mixing rate (with S.E.) in each of normal distribution by month for Australian farmed SBT harvested in 2008

2008 年に収穫された豪州畜養ミナミマグロの月別の各正規分布の平均尾叉長、標準偏差、混合率の推定値（±標準誤差）

FreshFrozen	Month	N_norm_dist	L_Mean_Mode1	L_Mean_Mode2	L_Mean_Mode3	L_Mean_Mode4	L_SD_Mode1	L_SD_Mode2	L_SD_Mode3	L_SD_Mode4
Fresh	3	1		106.0 cm				4.49 cm		
Fresh	4	2	85.2 ±1.07cm	103.9 ±0.09cm			3.32 ±1.05cm	5.25 ±0.08cm		
Fresh	5	2		105.0 ±0.08cm	116.7 ±0.47cm			4.0 ±0.08cm	3.21 ±0.44cm	
Fresh	6	3	94.4 ±1.05cm	106.1 ±0.15cm	114.2 ±0.79cm		4.54 ±0.93cm	3.45 ±0.14cm	3.63 ±0.45cm	
Fresh	7	4	103.0 ±5.72cm	106.9 ±0.15cm	114.4 ±0.85cm	131.0 ±1.75cm	6.81 ±2.39cm	2.73 ±0.21cm	5.08 ±0.0cm	6.15 ±1.44cm
Fresh	8	4	95.5 ±0.44cm	107.9 ±0.12cm	118.1 ±0.18cm	129.2 ±1.0cm	3.92 ±0.0cm	4.03 ±0.16cm	3.54 ±0.23cm	5.55 ±1.00cm
Fresh	9	2		106.3 ±0.25cm	116.5 ±0.38cm			3.75 ±0.18cm	5.61 ±0.26cm	
Fresh	10	2		106.1 ±0.56cm	115.2 ±0.0cm			3.46 ±0.36cm	4.83 ±0.27cm	
Freezer vessel	7	4	100.3 ±15.94cm	106.6 ±0.45cm	115.4 ±0.63cm	119.0 ±37.0cm	6.34 ±7.11cm	3.36 ±0.65cm	2.0 ±1.25cm	7.21 ±17.84cm
Freezer vessel	8	4	94.9 ±1.06cm	105.0 ±0.0cm	114.1 ±0.54cm	128.0 ±5.14cm	4.98 ±0.86cm	3.08 ±0.21cm	4.72 ±0.63cm	3.89 ±4.51cm
Freezer containers	8	3	95.1 ±0.42cm	104.4 ±0.11cm	113.3 ±0.33cm		4.00 ±0.33cm	3.11 ±0.13cm	4.13 ±0.24cm	

FreshFrozen	Month	N_norm_dist	%Mode1	%Mode2	%Mode3	%Mode4
Fresh	3	1		101.4 ±1.92%		
Fresh	4	2	3.9 ±0.93%	96.1 ±0.93%		
Fresh	5	2		90.5 ±1.31%	9.5 ±1.31%	
Fresh	6	3	7.3 ±1.36%	74.2 ±4.68%	18.4 ±4.87%	
Fresh	7	4	21.0 ±16.79%	27.8 ±6.63%	43.7 ±13.38%	7.5 ±22.47%
Fresh	8	4	9.1 ±0.91%	53.0 ±2.23%	29.0 ±2.88%	8.9 ±3.75%
Fresh	9	2		36.0 ±3.73%	64.0 ±3.73%	
Fresh	10	2		24.5 ±5.48%	75.5 ±5.48%	
Freezer vessel	7	4	18.5 ±43.38%	64.6 ±43.0%	9.2 ±14.37%	7.6 ±62.75%
Freezer vessel	8	4	14.5 ±2.57%	43.2 ±6.11%	40.9 ±5.85%	1.4 ±8.84%
Freezer containers	8	3	19.0 ±1.69%	49.5 ±3.23%	31.5 ±3.65%	

Standard error of mixing rate of the largest mode was calculated using the delta method approximation, and likely too high as fails to allow for covariance.

Table 5. Age assignment for each normal distribution in the monthly length frequency of farmed SBT in 2008. Shading shows difference from the Base case.

2008 年のミナミマグロ畜養魚の月別体長組成における各正規分布の対応年齢。シェードは Base と異なる部分。

Base

Fresh/Frozen	Month	mode1	mode2	mode3	mode4
fresh	3	Age3			
fresh	4	Age2	Age3		
fresh	5	Age3	Age4		
fresh	6	Age2	Age3	Age3	
fresh	7	Age3	Age3	Age3	Age5
fresh	8	Age2	Age3	Age4	Age5
fresh	9	Age3	Age3		
fresh	10	Age3	Age3		
freezer vessel	7	Age3	Age3	Age3	Age4
freezer vessel	8	Age2	Age3	Age3	Age5
freezer container	8	Age2	Age3	Age3	

Lower age case

Fresh/Frozen	Month	mode1	mode2	mode3	mode4
fresh	3	Age3			
fresh	4	Age2	Age3		
fresh	5	Age3	Age4		
fresh	6	Age2	Age3	Age3	
fresh	7	Age2	Age3	Age3	Age5
fresh	8	Age2	Age3	Age4	Age5
fresh	9	Age3	Age3		
fresh	10	Age3	Age3		
freezer vessel	7	Age2	Age3	Age3	Age4
freezer vessel	8	Age2	Age3	Age3	Age5
freezer container	8	Age2	Age3	Age3	

Higher age case

Fresh/Frozen	Month	mode1	mode2	mode3	mode4
fresh	3	Age3			
fresh	4	Age2	Age3		
fresh	5	Age3	Age4		
fresh	6	Age2	Age3	Age4	
fresh	7	Age3	Age3	Age4	Age5
fresh	8	Age2	Age3	Age4	Age5
fresh	9	Age3	Age4		
fresh	10	Age3	Age3		
freezer vessel	7	Age3	Age3	Age4	Age4
freezer vessel	8	Age2	Age3	Age4	Age5
freezer container	8	Age2	Age3	Age4	

Table 6. Age compositions and amount caught by Australian surface fisheries for SBT farming estimated from the size data at harvest in 2008. The three cases reported correspond to those defined in Table 5.

2008 年の収穫時のサイズデータから推定した豪州巻き網漁業（畜養用）のミナミマグロ漁獲量及び年齢組成。3 ケースは Table 5 に対応。

Base case

Present estimate for imported to Japan

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		36,500	253,966	6,543	3,150	300,159	5,359
%		12%	85%	2%	1%	100%	

Present estimate raised to all Australian purse seine catch

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		39,491	274,776	7,079	3,408	324,754	5,798
%		12%	85%	2%	1%	100%	

Australian reported catch for purse seine[1)]

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Number	0	78,009	231,511	14,318	759	324,754	5,211
%	0%	24%	71%	4%	0%	100%	

Lower age case

Present estimate for imported to Japan

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		45,935	244,367	6,692	3,165	300,159	5,283
%		15%	81%	2%	1%	100%	

Present estimate raised to all Australian purse seine catch

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		49,699	264,390	7,240	3,424	324,754	5,716
%		15%	81%	2%	1%	100%	

Higher age case

Present estimate for imported to Japan

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		36,408	162,956	97,665	3,130	300,159	6,144
%		12%	54%	33%	1%	100%	

Present estimate raised to all Australian purse seine catch

	N_Age1	N_Age2	N_Age3	N_Age4	N_Age5	Total	ight in ton
Median		39,391	176,309	105,668	3,386	324,754	6,647
%		12%	54%	33%	1%	100%	

1) Total number of purse seine catch reported from Australia. Fish caught in November and December 2007 were included as fish one year older in 2008. Catches at age by month were estimated in the present study. These may be slightly different from those to be calculated by Australia, which are not available to date.

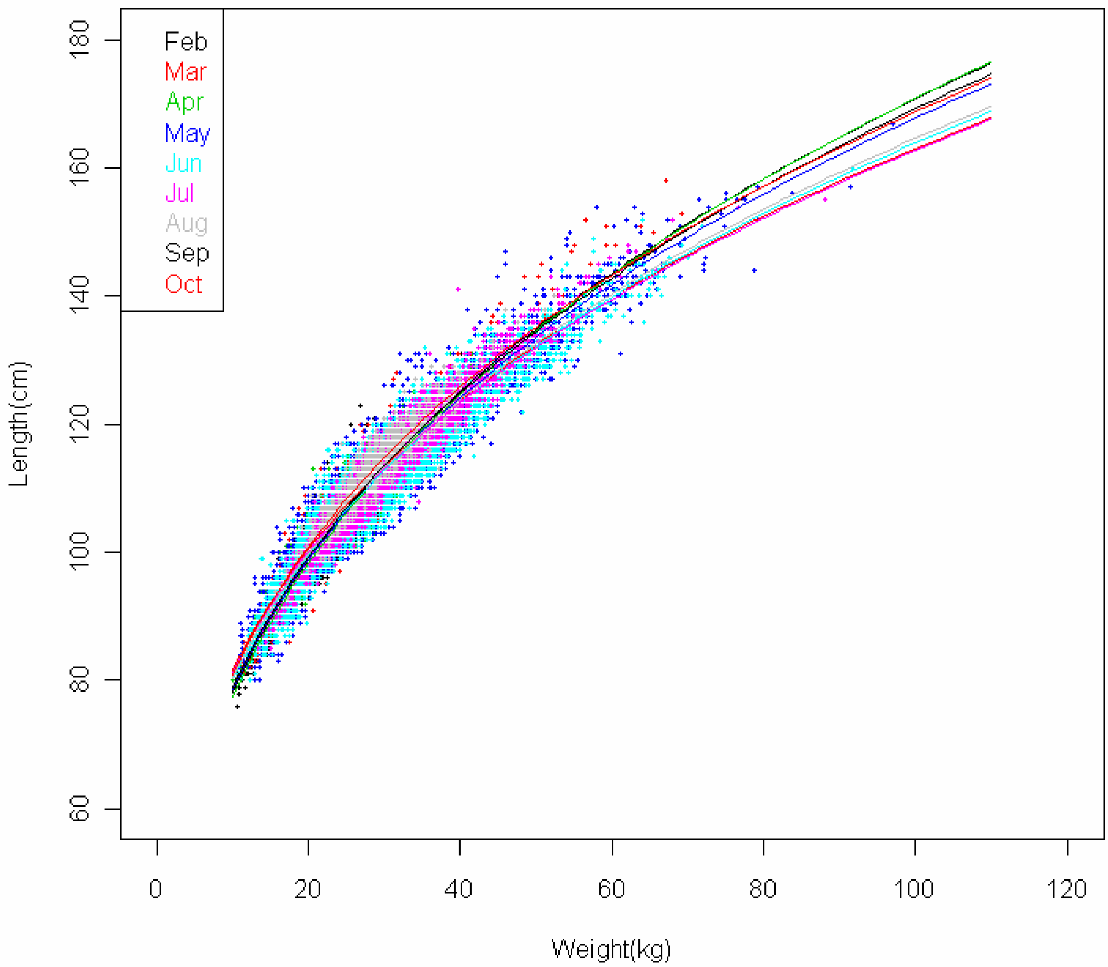

Fig. 1. Monthly weight (gilled and gutted in kg) – length (fork length in cm) relationship for Australian farmed SBT harvested in 2008

2008 年に収穫された豪州畜養ミナミマグロにおける月別の体重（鰓、内臓抜き kg）と体長（尾叉長 cm）の関係。N=57,233.

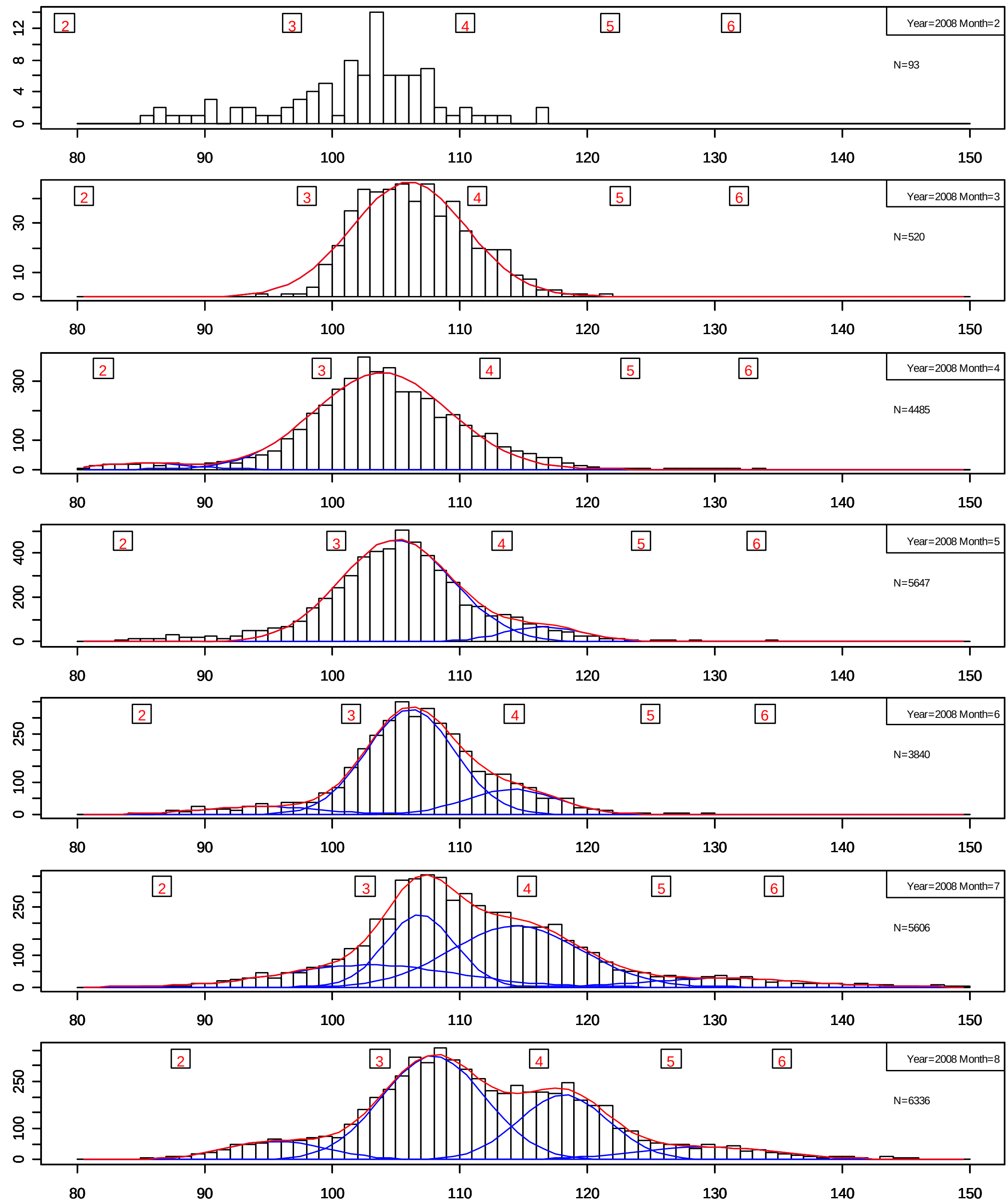

Fig. 2a. Monthly length frequency and estimated probability density functions of the normal mixture distribution of farmed SBT at harvest (for Fresh SBT). Mean monthly length at age of wild fish is shown in the squares.

畜養ミナミマグロ（生鮮出荷魚）の収穫時の体長頻度（棒）と推定した混合正規分布（線）。四角内は野生魚の年齢月別平均体長。

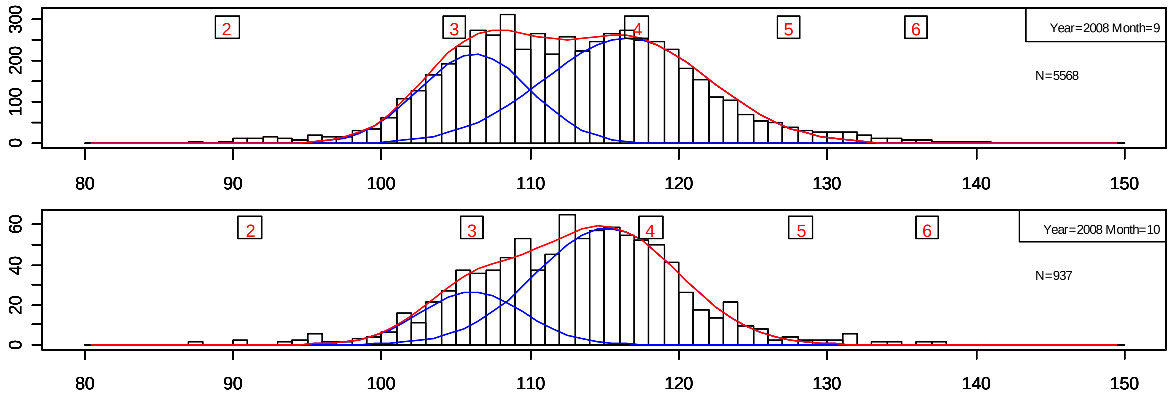

Fig. 2b. (Contd.) (For fresh SBT)

（つづき）（生鮮）

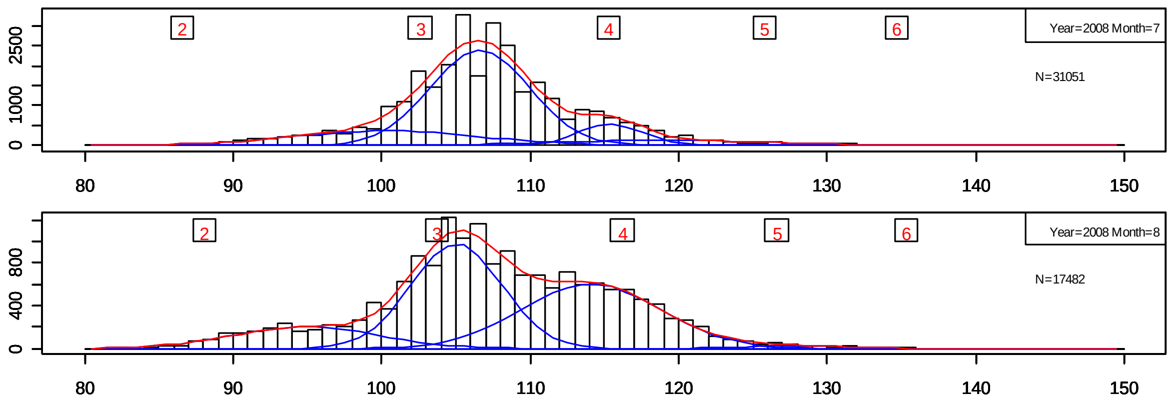

Fig. 2c. (Contd.) (For frozen SBT from freezer vessels)

（つづき）（冷凍運搬船）

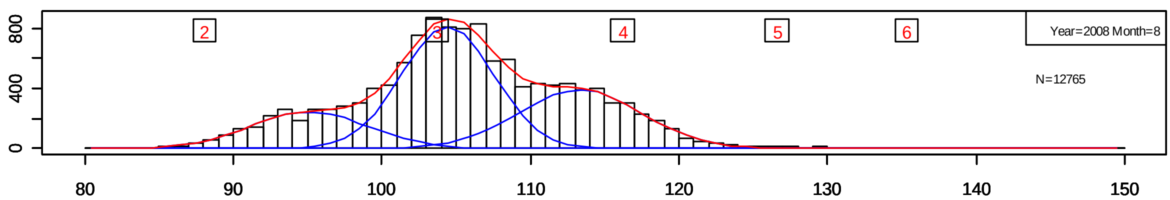

Fig. 2d. (Contd.) (For frozen SBT from freezer containers)

（つづき）（冷凍コンテナ）

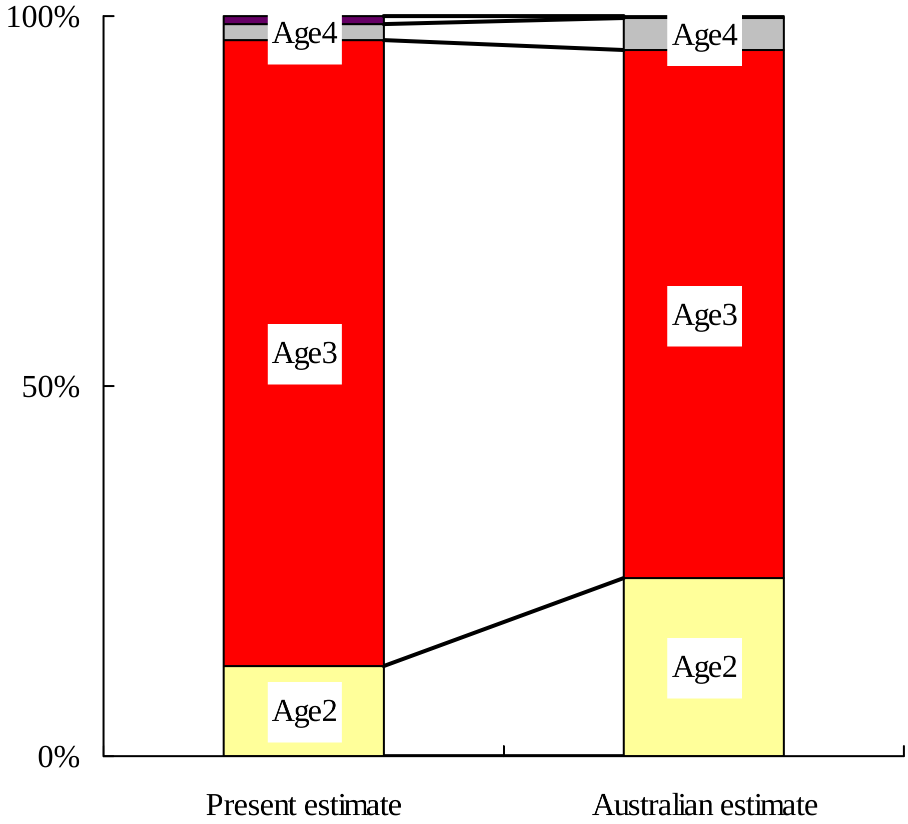

Fig. 3. Comparison of age compositions (by number) estimated in the present study with those reported by Australia to the CCSBT.　Fish caught in December 2007 were included as fish one year older in 2008.

本研究の推定結果と豪州政府が報告した年齢組成の比較．　2007 年 12 月に漁獲された魚は 2008 年の 1 歳高齢の魚に含めた。